US Army Corps of Engineers
Ice Engineering
U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire

Drilling Holes in Ice to Reduce Ice Jam Potential

Every winter, ice jams on northern rivers cause damages totaling millions of dollars to towns, bridges, levees and other structures. These damages result from ice floes impacting structures and from ice jam floods. Drilling holes in the ice cover in strategic reaches of the river to accelerate the deterioration of the icecover is one method that can be used to reduce the potential for ice jams. Figure 1 shows a posthole digger used to drill holes in the ice.

Figure 1. Tractor and posthole digger used to drill holes in ice. Note the use of turf tires to help reduce the localized stresses on the ice.

This concept has been applied in Oconto, Wisconsin, at the confluence of the Oconto River and the Green Bay in response to a series of ice jam floods that had flooded the downtown area in the spring of 1986, 1989 and 1990 and caused extensive damages to businesses and homes along the Oconto River. The damages incurred in 1990 alone totaled over $120,000 for Oconto (Jones 1995, personal communication). Figure 2 is a map of the City of Oconto; the darkened area indicates the section of the city typically affected by the ice jam floods.

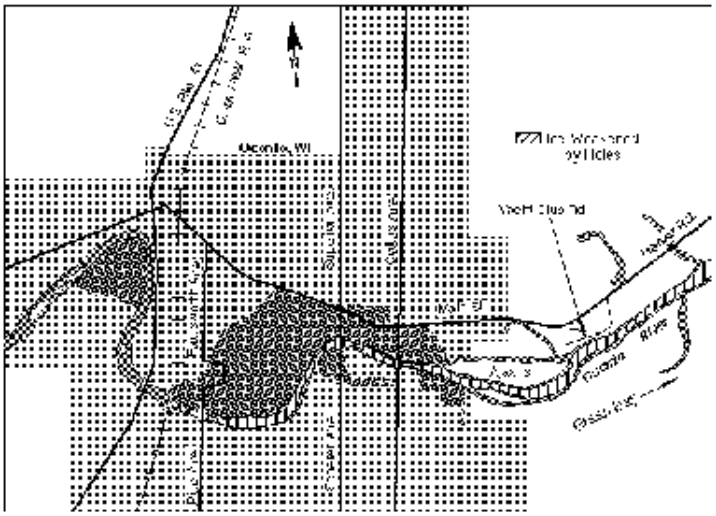

Figure 2. The City of Oconto, Wisconsin, indicated by the shaded area. Flood-affected areas are indicated by the darkened region. (River flow is from left to right.)

Frequently ice jams occur when ice floes encounter a downstream stationary ice cover that arrests these floes, causing a jam to form. The shallow river slope, presence of islands, and meandering nature of the Oconto River (see Fig. 2) not only encourage the persistence of the stable ice cover, but also provide several potential locations for ice jamming within the city limits. Historically, ice jams have formed at the upstream islands (left side of Fig. 2), the river bend between Pine Avenue and Scherer Avenue, and at Ajax Island. Weakening or elimination of the stable ice cover at these locations will allow floes to move through these problem reaches unhindered, thus reducing the probability for ice jam formation.

Drilling holes in the ice cover can help reduce the potential for ice jam formation by weakening the icecover through that reach. In addition to reducing the integrity of the existing ice cover, the holes increase the roughness of the bottom of the ice cover, increasing the shear stress acting on the bottom of the ice, which can force the ice to break up sooner. The added roughness also increases the turbulence on the underside of the ice, which enhances heat transfer from the water to the ice, thereby accelerating ice melt. Deterioration of the ice cover is further hastened by solar heating of the water exposed to sunlight through these holes.The resulting weakened and thinned cover readily breaks up, allowing clear passage of upstream floes through the problem reach.

Drilling holes: Oconto experience

Past efforts to alleviate flooding in Oconto included dredging the river channel and blasting the ice jam.Dredging deepens the channel and improves flow through the problem reach. Although this was an effective solution, the annualized cost of regular dredging is around $25,000, a hefty annual expense for a small community like Oconto.

Blasting has limited appeal because it does not prevent ice jams and the associated flooding, but merely shortens its duration. Furthermore, safety issues related to putting personnel on an unstable ice jam to set the charges, handling of the explosives, and the uncontrolled hurling of ice and debris upon detonation make the use of blasting to release ice jams a hazardous operation.

In 1991 the City of Oconto began ice weakening operations on the Oconto River. That first year, upon CRREL's recommendation, the ice was weakened by cutting trenches in the ice with machinery similar to that used on the Beaurivage River in Canada (Jolicoeur et al. 1984). However, much of the ice in the reach was not thick enough to support the trenching equipment, so the city tried to weaken the ice by drilling holes as well.

In 1991 the holes were drilled with hand-held gas-powered ice augers ordinarily used for ice fishing. Drilling the holes with hand-held augers proved to be a laborious task, so in 1992 the city purchased a posthole digger that mounted on the back of a lawn and garden tractor to drill the holes in the ice (Fig. 1).The 9-inch-diameter holes were drilled about 8 to 10 feet apart in the pattern indicated in Figure 3. The objective was to place this pattern over the thalweg of the river. The cross-hatched area shown above in Figure 2 indicates the river reach in which the holes were drilled, a distance of about three miles.

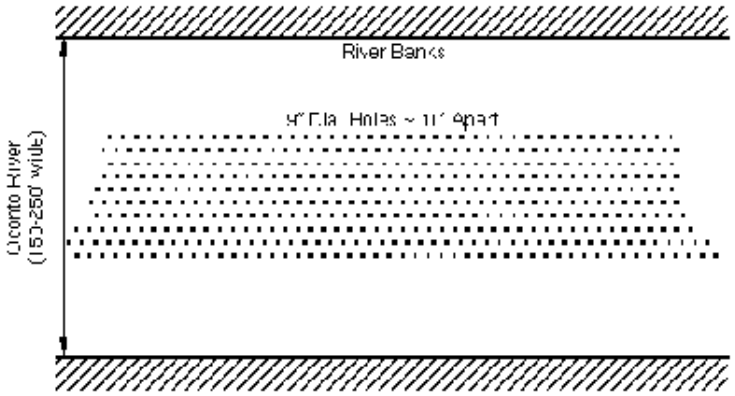

Figure 3. Pattern of holes drilled in the river ice cover in Oconto.

For the first three years that this operation was carried out, the City of Oconto used an off-the-shelf augur with a standard screw tip to drill the holes. This tip, designed for soils, had a tendency to load up when drilling in ice. In 1995 Oconto developed a new tip, which improved the performance of the posthole digger when cutting ice. The new tip is shown mounted on the auger in Figure 4.

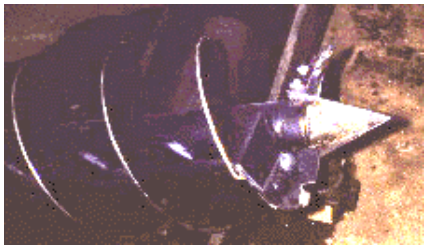

Figure 4. Spade tip developed by the City of Oconto, mounted on the posthole auger.

With the new, spade-shaped tip, the auger's penetration rate increased to about two inches per second in ice. This made it possible for holes to be drilled in the 14- to 16-inch ice cover at a rate of 150 to 200 holes per hour.

The entire operation takes about two weeks using one tractor with the mounted posthole digger.

Although the posthole digger requires only one person to operate it, a second person is on site during the operation for safety purposes. Carrying out this operation costs the City of Oconto about $2,000 annually.That amount includes maintenance costs and labor, but does not include annualization of the $900 cost for the posthole digger. Tractor costs are not considered because the tractor normally is used during the summer months to maintain city lawns and gardens. The yearly cost of drilling holes, therefore, is less than two percent of the cost of damages incurred by the 1990 flood.

Results

Figure 5 shows the observed profile of the ice cover around the holes during the melt period. The original hole is shown by profile 1. As melting progresses, the hole diameter at the ice surface remains nearly constant; however, at the water level and below, the hole progressively enlarges. Profiles 2 and 3 illustrate this progressive melting around the holes that is caused by the water flowing under and swirling in the holes. Taking into consideration the pattern of holes drilled (Fig. 3) and overlapping of the effect shown in Figure 5, the net result is a much thinner ice cover in the region where the holes have been drilled, which reduces the ice volume and the integrity of the ice cover in the drilled reach.

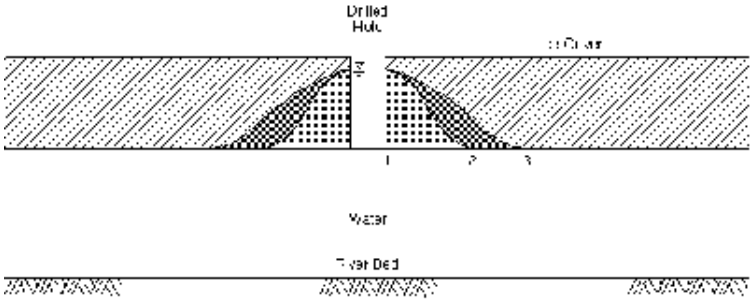

Figure 5. Typical observed ice profile around a hole. The original hole is shown by profile 1. Profiles 2 and 3 show the progressive melting of ice away from the hole.

The effectiveness of this method to reduce ice jams depends on the amount of time that elapses between the time the holes are drilled and when the upstream ice runs occur. Generally, the earlier in the year the holes are drilled, the more time there is for the ice cover to deteriorate; consequently, the holes have a greater chance to effectively minimize an ice jam. However, if the holes are drilled too early in the winter, they will simply refreeze and all benefit from drilling the holes will be lost.

The drilling operation is started the last week in February. Historical data show that for the City of Oconto, this is about the time that average air temperatures begin to moderate, slowing or halting ice growth. Thus there is little chance of the holes refreezing after they are drilled. Because the ice normally goes out at the end of March, there is almost a full month for the ice to thin and deteriorate before going out.

During the four years that the City of Oconto has been weakening the ice cover by drilling holes, they have not had an ice-jam-related flood. However, the conditions at Oconto during these four years have been such that the risk of having an ice jam has been low to moderate, so it is difficult to say conclusively that the hole drilling operation has been a success. Nevertheless, the river ice in the affected reach has been observed to thin and deteriorate more rapidly than the adjacent cover, which

suggests that the holes are effective at advancing the deterioration of the ice cover, which in turn should reduce the potential for an ice jam.

Acknowledgments

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